

# First Record of Red Colouration in Atlantic Cod *Gadus morhua* L. (Gadiformes: Gadidae) from the North Sea

Agnieszka Rybczyk<sup>1\*</sup>, Przemysław Czerniejewski<sup>2</sup> & Mariola Janowicz<sup>3</sup>

<sup>1</sup>Department of Aquatic Zoology, West Pomeranian University of Technology, Szczecin, Poland

<sup>2</sup>Department of Fisheries Management, West Pomeranian University of Technology, Szczecin, Poland

<sup>3</sup>Department of Biology and Environmental Science, Concordia University College of Alberta 7128 Ada Blvd, Edmonton AB T5B 4E4, Canada

**Abstract:** This study is concerning biological characteristics of the Atlantic cod (*Gadus morhua* L.) with unique red colouration, recorded for the first time from European waters. The “red”-coloured cod (total length = 512 mm, total weight = 1291.6 g) was caught in the North Sea on 15<sup>th</sup> July 2013.

**Key words:** *Gadus morhua*, Atlantic cod, North Sea, unique colouration.

## Introduction

The current distribution of the Atlantic cod is extensive: from Cape Cod in the south to Spitzbergen in the north (GEFFEN et al. 2006). In their geographical range, cod populations vary in growth rates, life-history patterns, population structure, fecundity and fish condition (BRANDTER 2005). IMSLAND & JONSDOTTIR (2003) reported that, in addition to genetic and morphological differences among populations, there are noticed differences within the populations, including a variety of colouration patterns (WROBLEWSKI et al. 2005, SHERWOOD & GRABOWSKI 2010).

Morphological changes in skin colouration of fish are often accredited to environmental conditions, in which they live (JONSSON & JONSSON 1993, AHILAN & PRINCE JEYASEELAN 2001). GOSSE & WROBLEWSKI (2004) studied Atlantic cod with unusual colouration from the coastal waters of Newfoundland and Labrador, Canada and distinguished three colouration variants: “red”, “brown” and “golden-brown”. SHERWOOD & GRABOWSKI (2010) examined the life-history implications of colour variation in the Gulf of Maine cod. Atlantic cod with these specific colourations are rarely caught in other parts of their range. One “gold”-coloured individual was captured in the

waters of the Svalbard Bank in the North Atlantic (WIĘCASZEK 2009). Although, there are anecdotal fishermen reports of “coloured” cod encountering within the European waters, with the exception of the only “brown”-coloured cod that had been caught in the North Sea and reported by RYBCZYK et al. (2014), coloured variants of cod have not been reported yet.

The objective of this study was to examine and document biological characteristics of the first “red”-coloured Atlantic cod (*Gadus morhua* L.) specimen that was trawl-caught on 15<sup>th</sup> July 2012 at depth of 22 m, inshore of Denmark in the North Sea (GPS location: 57°41.01'N; 9°17.5'E; Fig. 1).

## Materials and Methods

After being captured, the “red” cod was kept on ice and transported to the laboratory at the Department of Zoology at the West Pomeranian University of Technology, Szczecin, Poland. Total and standard lengths were measured with electronic callipers to the nearest 0.1 mm. Electronic balance was used to obtain the total weight with the precision of 0.1 g.

\*Corresponding author: agnieszka.rybczyk@zut.edu.pl

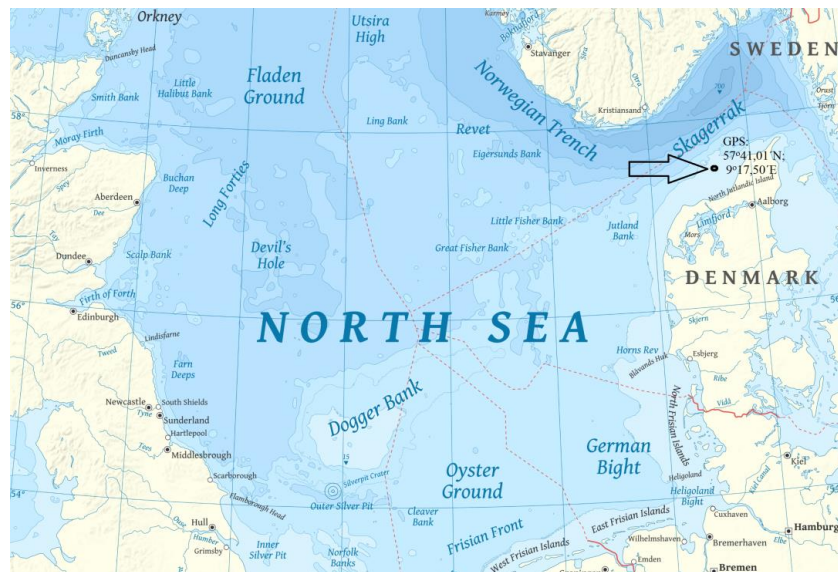


Fig. 1. Location of the “red” Atlantic cod captured in December 2013.



Fig. 2. A “red” cod captured in the North Sea.

The red colouration was examined and confirmed using the RGR method proposed by SHERWOOD & GRABOWSKI (2010). Sagittal otoliths were used to estimate age and growth rates (GJØSÆTER & DANIELSEN 2011). Diet analysis was performed on the stomach contents following HYSLOP (1980). The method described by VITALE et al. (2006) was used for the macroscopic and histological examination of gonads.

## Results

The “red” cod was a male with a total length of 512 mm and weight of 1291.6 g. Its age was estimated at three years. The stomach content analysis revealed

stomach fullness at 60%, half of which was owing to brittle stars (Ophiuroidea). The remaining, less important food components were shrimps (Mysidacea), amphipod crustaceans (Gammaridae), crabs (*Cancer pagrus*) and fish fragments. Vegetarian food (algae and vascular plants) and detritus were also found in the stomach content.

This uniquely coloured cod had a characteristic burgundy to red dorsal body surface, slightly brighter but more intense red sides and lightly coloured, bright ventral surface. The dorsal surface of the head and the body and the lateral surfaces were speckled with numerous dark spots. The fins were dark red with the first rays of the pectoral fins being intensively red (Figs. 2 and 3).



Fig. 3. First rays of the pectoral fins being intensely red.

## Discussion

URSIN (1984) reported that the Atlantic cod from the North Sea reaches 356-412 mm total length. The analysis of the length growth rate indicated that during the first year, the “red” cod attained 318 mm and 480 mm in the second year. Age and gonad analysis indicated that this fish was sexually immature. This corresponds to the records of the North Sea cod, which usually reaches sexual maturity at the age 5 or 6 (OOSTHUIZEN & DAAN 1974, RIJNSDORP et al. 1991).

The unique skin colouration of fish depends on the variety and concentration of pigments found in the chromatophores within the skin. Brown and black pigments are contained in the melanophores, while red, orange and yellow are found in the erythrophores and xanthophores, respectively (BAGNARA & HADLEY 1973). The factors responsible for the actual colouration, however, are very difficult to determine. GOSSE & WROBLEWSKI (2004) concluded that the red colour in a coastal cod population in Labrador was attributable to a diet rich in carotenoids, e.g. benthic invertebrates. They found that, following the diet switch experiment (invertebrates to fish), the “red” and “brown” cod lost their pigmentation. Similarly, BIGELOW & SCHROEDER (1953) suggested that colour variation of cod in the Gulf of Maine was no more than an expression of diet and habitat preferences, which could vary over cod’s lifetime. The results of SHERWOOD & GRABOWSKI (2010) indicate

that although colour expression in cod can be transient under certain circumstances, the expression of red colour is likely associated with a very distinct life-history strategy. Differences in diet, habitat preferences, growth and body shape are all consistent with the existence of alternative life-history strategies in cod (and possibly ecotype variation), as shown for other species of fish (JONSSON & JONSSON, 1993, BERNATCHEZ et al. 1996, KERR et al. 2009). It is unknown whether this life-history variation results from a conditional strategy, e.g. partial migration or genetic differences.

## References

- AHILAN B. & PRINCE JEYASEELAN M. J. 2001. Effects of different pigment sources on colour changes and growth of juvenile *Carassius auratus*. *Journal of Aquaculture in the Tropics* 16: 29-36.
- BAGNARA J. T. & HADLEY M. E. 1973. *Chromatophores and Colour change*. New Jersey: Prentice-Hall. 202 p.
- BERNATCHEZ L., VUORINEN J. A., BODALY R. A. & DODSON J. J. 1996. Genetic evidence for reproductive isolation and multiple origins of sympatric trophic ecotypes of whitefish (*Coregonus*). *Evolution* 50: 624-635.
- BIGELOW H. B. & SCHROEDER W. C. 1953. *Fishes of the Gulf of Maine*. US Fish and Wildlife Service Fisheries Bulletin 53, 577 p.
- BRANDER K. 2005. Spawning and life history information for North-Atlantic cod stocks. ICES Cooperative Research Report 205.
- GEFFEN A. J., FOX C. J. & NASH R. D. M. 2006. Temperature-

- dependent development rates of cod *Gadus morhua* eggs. *Journal of Fish Biology* 69: 1060-1080.
- GJØSÆTER J. & DANIELSSEN D. S. 2011. Age, growth and otolith annulus formation of cod (*Gadus morhua*) in the Risør area on the Norwegian Skagerrak coast during 1986-1996. *Marine Biology Research* 7: 281-288.
- GOSSE K. R. & WROBLEWSKI J. S. 2004. Variant colourations of Atlantic cod (*Gadus morhua*) in Newfoundland and Labrador nearshore waters. *ICES Journal of Marine Science* 61: 752-759.
- HYSLOP E. J. 1980. Stomach content analysis – a review of methods and their application. *Journal of Fish Biology* 17: 411-429.
- IMSLAND A. K. & JÓNSDÓTTIR Ó. D. B. 2003. Linking population genetics and growth properties of Atlantic cod. *Rev. Fish. Biol. Fish.* 13: 1-26.
- JONSSON B. & JONSSON N. 1993. Partial migration: niche shift versus sexual maturation in fishes. *Reviews in Fish Biology and Fisheries* 3: 348–365.
- KERR L. A., SECOR D. H. & PICCOLI P. M. 2009. Partial migration of fishes as exemplified by the estuarine-dependent white perch. *Fisheries* 34: 114-123.
- OOSTHUIZEN E. & DAAN N. 1974. Eggs fecundity and maturity of North Sea cod, *Gadus morhua*. *Netherlands J. Sea Res.* 8: 378-397.
- RIJNSDORP A. D., DAAN N., VAN BEEK F. A. & HEESSEN H. J. L. 1991. Reproductive variability in North Sea plaice, sole, and cod J. *Cons. Cons. Int. Explor. Mer* 47 (3): 352-375.
- RYBCZYK A., CZERNIEJEWSKI P. & ROKICKA-PREXMAJER A. (2014). First record of brown colouration of Atlantic cod (*Gadus morhua*, L.) from the North Sea. *Oceanologia* 56 (1): 159-163.
- SHERWOOD G. D. & GRABOWSKI J. H. 2010. Exploring the life-history implications of colour variation in offshore Gulf of Maine cod (*Gadus morhua*). *ICES Journal of Marine Science* 67.
- URSIN E. 1984. On the growth parameters of Atlantic cod as a function of body size. *Dana* 3: 1-20.
- VITALE F., SVEDANG H. & CARDINALE M. 2006. Histological analysis invalidates macroscopically determined maturity ogives of the Kattegat cod (*Gadus morhua*) and suggests new proxies for estimating maturity status of individual fish. *Journal of Marine Science* 63: 485-492.
- WIĘCĄSZEK B., ANTOSZEK J. & ANTOSZEK A. 2009. Comparative study of biometric characters of the „Golden” cod and a sample of cod of typical pigmentation (*Gadus morhua morhua* L.) captured in the Svalbard Bank. *EJPAU* 12 (2), #05.
- WROBLEWSKI J., NEIS B. & GOSSE K. 2005. Inshore stocks of Atlantic cod are important for rebuilding the east coast fishery. *Coastal Management* 33: 411-432.

Received: 03.04.2017

Accepted: 12.07.2017